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Special Scientific Report No. 11

POLLUTION SURVEY OF THE CUMBERLAND RIVER IN THE VICINITY OF NASHVILLE, TENN., AUGUST, 1936.

By

M. M. Ellis and B. A. Westfall

Chicago
1943

POLLUTION SURVEY OF THE CUMBERLAND RIVER IN THE VICINITY OF NASHVILLE, TENN., AUGUST, 1936[1]

by

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and

B. A. Westfall, Associate Aquatic Physiologist

INTRODUCTION

Following the request of Mr. N. H. Walker, Supervisor of the Protectors for the State of Tennessee, (State Game and Fish Commission) to the U. S. Bureau of Fisheries for an investigation of the Cumberland River in the vicinity of Nashville, Tennessee, with reference to stream pollution and fisheries, Mr. B. A. Westfall, Bioassayist, U. S. Bureau of Fisheries, was detailed to Nashville, and was actively engaged in field work on the Cumberland River, August 3 to 8 inclusive, covering a total of some 60 miles of the Cumberland River from the duPont Rayon Mills (31 miles by river upstream from Nashville) to a point about 20 miles below Nashville. During this period the State of Tennessee supplied boats and other field assistance which is gratefully acknowledged. At the close of field work a truck load of samples representing 120 different collections was taken to the Columbia (Mo.) Laboratories where detailed chemical and biological assays were made.

The present report presents in condensed form the summarized findings based on these field and laboratory studies.

METHODS

The analytical procedures followed for water analyses were those approved by the American Public Health Association (1933), and the biological assay methods those described by Ellis (1936). In all nearly 500 standardized fish were used in the determination of toxicity values for the several types of industrial effluents in the Nashville area, and these data were supplemented by the various routine bioassay tests of all samples as regularly carried out in Columbia Laboratories. All assays and analyses were made in quadruplicate.

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[1] Submitted October 7, 1936.

LIST OF LOCALITIES

The several stations at which samples were collected in the Nashville area are listed below. These have been arranged in sequence, moving downstream from Old Hickory, Tennessee, the most upstream point on the Cumberland River visited in this study. The abbreviation "Lno" refers to locality number in field notes.

Lno 1310. August 4, 1936. Cumberland River, 300 yards upstream from duPont Rayon Slough at Old Hickory, Tennessee.

Lno 1311. August 4, 1936. duPont Rayon Slough, at Old Hickory, 31 miles by river upstream from Nashville, Tennessee.

Lno 1312. August 4, 1936. Cumberland River, one-half mile downstream from duPont Rayon Slough outlet at Old Hickory.

Lno 1313. August 4, 1936. Cumberland River at Old Hickory Bridge.

Lno 1314. August 5, 1936. Cumberland River at Shelby Point one and one-half miles upstream from Nashville. Mid channel and 200 yards above the most upstream sewer from Nashville.

Lno 1315. August 5, 1936. Nashville city sewer No. 1, i.e., the most upstream sewer entering the Cumberland River from Nashville.

Lno 1316. August 5, 1936. Cumberland River, midstream about 100 yards upstream from the second sewer and below the first sewer flowing into the river from Nashville.

Lno 1317. August 5, 1936. Nashville city sewer No. 2, i.e., second sewer entering the Cumberland River from Nashville. This sewer carries effluent from the White Way Laundry but the discharge was blue-gray and fairly clear rather than soapy at the time the sample was taken.

Lno 1318. August 5, 1936. Nashville City Hospital sewer, at the east, i.e., upstream, edge of the town.

Lno 1319. August 5, 1936. Cumberland River, mid.channel about 300 yards upstream from Sparkman Street Bridge and above the mouth of the seventh city sewer from Nashville.

Lno 1320. August 5, 1936. Nashville City sewer No. 7, a little upstream from Sparkman Street Bridge; a large sewer five feet wide, discharging a stream three feet deep carrying the waste from two laundries.

Lno 1321. August 5, 1936. Nashville city sewer No. 8, the first sewer downstream from the Sparkman Street Bridge. Effluent contained large quantities of undisintegrated feces and hotel wastes.

Lno 1322. August 5, 1936. Flume from Heinz Pickle Factory. Rather clear effluent gushes with powerful current from a 14-inch pipe just under the surface of the river.

Lno 1323. August 5, 1936. Nashville city sewer No. 10, 200 yards upstream from the Woodland Street Bridge. This sewer carries the effluent from the Ideal and Model Laundries as well as household sewage and much undisintegrated fecal material was noted floating at the surface of the river for several hundred yards below its outlet.

Lno 1324. August 5, 1936. Cumberland River, mid channel 35 feet upstream from the Louisville and Nashville Railroad Bridge, and about 400 yards downstream from the flume from the Heinz Pickle Factory.

Lno 1325. August 5, 1936. Waste pipe from the Nashville Heat and Gas Company Plant, about 200 yards downstream from the Louisville and Nashville Railroad Bridge. This effluent produced an oily appearance on the surface of the river and had a pronounced coal tar odor, and was distinctly blackish in color.

Lno 1326. August 6, 1936. Nashville city sewer No. 11. Just upstream from the Jefferson Street Bridge. A very large sewer perhaps 16 feet in diameter and flowing one-third full with a strong although quiet current. A brown scum one and one-half to two inches thick covers the surface of the water about the outlet of this sewer. There were also noted large quantities of undisintegrated fecal material and some garbage on the surface of the river. This sewer receives contributions from Gulf, Standard Oil and Sinclair Oil Company refineries.

Lno 1327. August 6, 1936. Cumberland River, mid channel halfway between Jefferson Street Bridge and the Neuhoff Packing Company Plant.

Lno 1328. August 6, 1936. Flume from Neuhoff Packing Plant, a pipe about 16 inches in diameter discharging over a pile of rocks from which the effluent drained into the river. The effluent contained considerable blood and the rock pile and vicinity were fouled with much animal waste including pieces of intestine, tapeworms, and intestinal contents.

Lno 1329. August 6, 1936. Flume from the Nashville-Jacobs Packing Company plant, discharging into narrow ditch eroded in the earth embankment. The effluent carried much blood and quite a quantity of animal debris.

Lno 1330. August 6, 1936. Cumberland River, mid channel, half way between Nashville Island and Lock 1. Surface of the water with floating scum and oily streaks. River bottom emitting many bubbles of gas from decomposition of organic material in the 5 inch layer of bottom silt. Leeches and tubifex worms very numerous in the shallow water along shore.

Lno 1331. August 6, 1936. Cumberland River, mid channel 300 yards below the dam of Lock 1.

Lno 1332 A and B. August 6, 1936. Flume from Victor Chemical Company plant, West Nashville, Tennessee. A 15 inch pipe discharges a grayish black effluent at the top of a rocky cliff some 175 feet high. The discharge reaches the river in two small streams and produces a dark streak in the river for a little distance downstream. This is the factory sewer and carries laboratory wash water. Samples taken just as the little streams entered the river.

Lno 1333. August 6, 1936. Flume from Victor Chemical Company Plant, West Nashville. Flume from vicinity of a large wooden tank at the top of the cliff, discharged, intermittently, through a deep cut in the face of the limestone rock. The effluent before reaching the river, about 100 yards below that from Lno 1332, spread out over the limestone which was stained yellow-brown and devoid of vegetation. This flume carries back wash from water purification plant. Sample taken from stream just before entering the river.

Lno 1340. August 8, 1936. Victor Chemical Company sewer and back wash from water filters, samples taken at the plant. These samples are comparable to those from Lno 1332A and B and Lno 1333 respectively.

Lno 1334. August 6, 1936. Stream from flume of the Federal Chemical Works, discharging a grayish effluent at the top of a high limestone cliff some 175 feet above the river. This waste has cut a deep narrow channel in the face of the limestone. Sample from near the river.

Lno 1341. August 8, 1936. Effluent from open ditch sewer just as it leaves the Federal Chemical Works.

Lno 1335. August 7, 1936. Stream entering the river from the flume leaving the Tennessee Fertilizer Company plant. The flume discharges its waste at the top of the cliff and the effluent has cut a narrow-deep groove in the limestone as it ran down to the river. This effluent is derived under conditions similar to that from the Federal Chemical Works which also manufactures super-phosphates. Samples from close to the river - a strong odor of ammonia was noted about this effluent.

Lno 1336. August 7, 1936. Sewer from the State Prison discharges over the face of a limestone cliff about 150 feet above the river. This sewer carries manufacturing as well as household wastes. Sample from near the river.

Lno 1337. August 7, 1936. Cumberland River in mid channel three fourths of a mile downstream from the State Prison sewer.

Lno 1344. August 8, 1936. Richland Creek in West Nashville, sampled 20 yards upstream from a bridge which is one-fourth of a mile above the Teas Extract and Mead Paperboard Companies but 6 miles below a small domestic sewer. Stream very small falling over a rocky bed. Small minnows were noted in one of its pools.

Lno 1342. August 8, 1936. An open ditch flume from the Teas Extract Company factory was sampled about 200 feet below the plant, carried a dark coffee-colored effluent. This factory extracts tannic acid from chestnut wood and bark.

Lno 1343. August 8, 1936. Mead Paperboard Company, West Nashville. Situated just a few yards below the Teas Extract Company. Uses the same waste flume as the Teas Extract Company. Four samples of wastes were taken:

A. - Mixture of pulp mill, boiler refuse, and Teas Extract.
B. - Same as A but diluted with river water.
C. - Paper mill effluent only.
D. - Mixture of above as it goes to Richland Creek.

Lno 1338. August 7, 1936. Richland Creek in West Nashville, was sampled 150 yards upstream from its junction with the Cumberland River. Width of Creek 30 to 35 feet; depth 4.5 feet; current moderate; water blackish. Richland Creek receives the effluents from the Teas Extract Company and the Mead Paperboard Company two and one-half miles upstream from its mouth.

Lno 1339. August 7, 1936. Cumberland River, in West Nashville, about one mile downstream from Richland Creek and one-half mile upstream from the Williamson Ferry. This is about 16 miles by river from Nashville.

CONDITIONS IN CUMBERLAND RIVER

a. Water conditions.--The Cumberland River in the Nashville area during the first week in August 1936, varied from 3 to 45 feet in depth at various stations where samples were collected. The water temperature averaged 28.7°C the specific conductance about 800 mho x 10^{-6} at 25°C.; the hydrogen-ion concentration, pH 7.7; and the fixed carbonates, the equivalent of 16.9 cc. of carbon dioxide per liter. These basic physico-chemical characteristics of the Cumberland River are within the average limits for streams of the Mississippi System during the summer months particularly, those passing through limestone country, and present no hazards to fish life.

The dissolved oxygen, biochemical oxygen demand, and ammonia content of the Cumberland River in the Nashville area, however, during this same period indicate very definitely organic pollution of large proportions. The summarized data on the dissolved oxygen and ammonia are presented in graph form (figure 1). In this graph the oxygen and ammonia limits for good fish fauna as found in detailed study of many thousand cases from streams of the United States (Ellis, 1935, and 1936) are indicated by horizontal dotted lines. The minimum value for dissolved oxygen is 5 p.p.m. and maximum for ammonia 1.5 p.p.m.

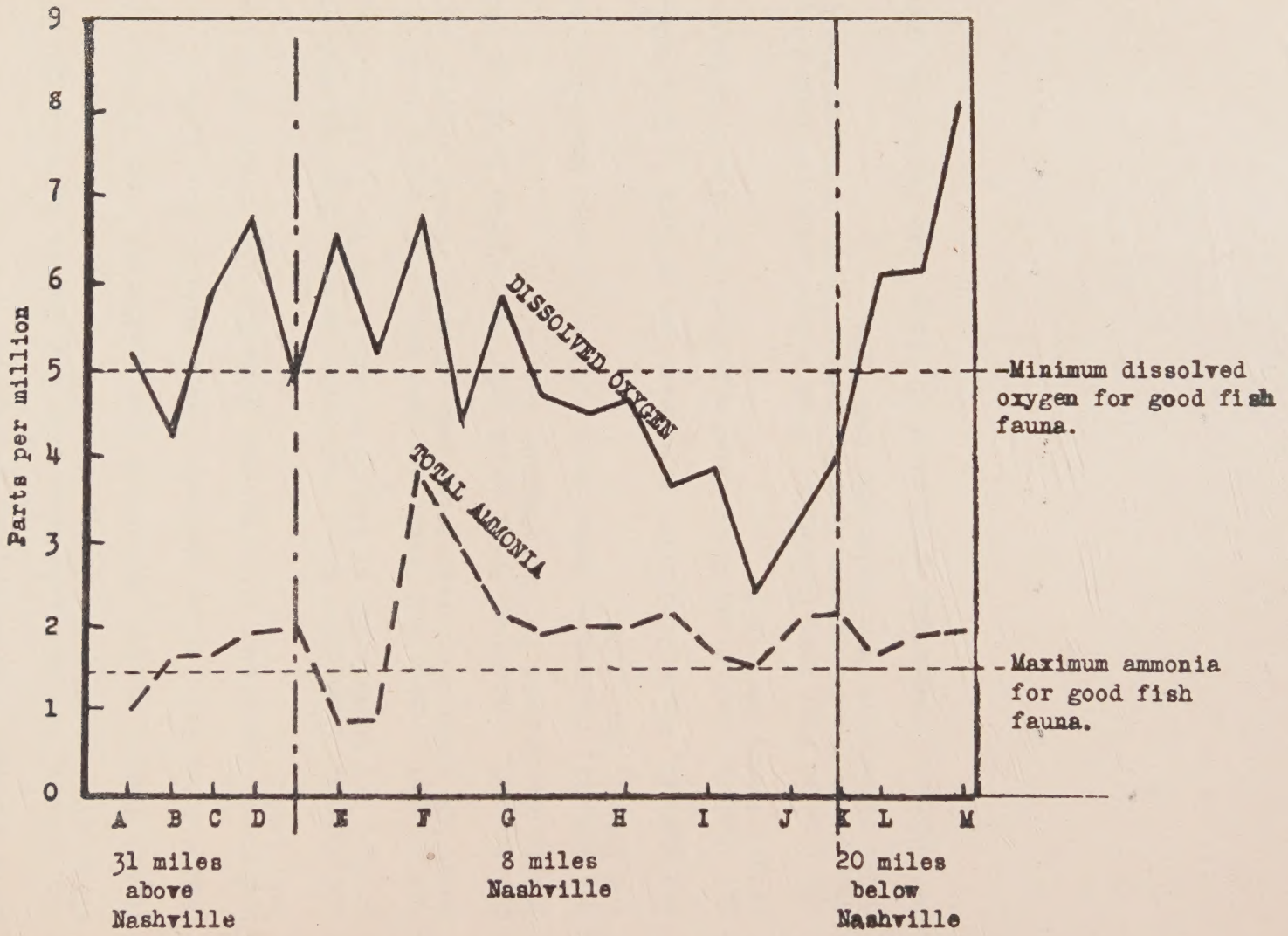

Figure 1. Dissolved oxygen and total ammonia in waters of the Cumberland River, Nashville, Tennessee, Area first week of August, 1936, from Old Hickory, Tennessee, through Nashville to a point 20 miles below Nashville. Localities designated by letters, see following page.

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Description of Cumberland River Localities

indicated on Figure 1.

A - Old Hickory, Tenn., 300 yards upstream from duPont Rayon Slough, 31 miles upstream from Nashville, Lno. 1310.

B - Old Hickory, one-half mile downstream from duPont Rayon Slough, 30 miles upstream from Nashville, Lno. 1312.

C - At Old Hickory Bridge, Downstream from Localities A and B, Lno. 1313.

D - Shelby Point 1-1/2 miles upstream from Nashville, Lno. 1314.

E - Midstream, Cumberland River between Nashville city sewers No's 1 and 2, Lno. 1316.

F - Mid channel, Cumberland River, 300 Yards upstream from Sparkman Street Bridge, and above mouth of Nashville city sewer No. 7, Lno. 1319.

G - Mid channel, Cumberland River, upstream side of L. and N. R. R. bridge, about 400 yards downstream from flume of Heinz Pickle Factory, Lno. 1324.

H - Mid channel, Cumberland River about half way between Jefferson Street Bridge and Neuhoff Packing Company, Lno. 1327.

I - Mid channel, Cumberland River about half way between Nashville Island and Lock 1, Lno. 1330.

J - Mid channel, Cumberland River just below dam of Lock 1, Lno. 1331.

K - Mid channel, Cumberland River three-quarters of a mile downstream from prison sewer, Lno. 1337.

L - Mid channel near West Nashville, about 1 mile below Richland Creek and one-half mile upstream from Williamson Ferry, approximately 16 miles downstream from Nashville, Lno. 1339.

M - Mid channel, Cumberland River about 20 miles below Nashville, Lno. 1345.

Starting with the Cumberland River above Old Hickory, Tennessee, as a basis for comparison the dissolved oxygen was found to be above the minimum for good fish fauna and the ammonia below the maximum, that is, water conditions as regards these two gases were quite satisfactory for fish life. Below the outlet from duPont Rayon Company Slough, Station "B", the dissolved oxygen fell to near 4 p.p.m., although it rose again at the Old Hickory Bridge, Station "C" and continued above 5 p.p.m. to beyond a point below Nashville City Sewer 6. In the approximately 30 miles between Old Hickory and the city limits of Nashville, at the time of this survey the dissolved oxygen content of the river water was satisfactory to good for fish life, with the exception of the zone just below the mouth of duPont Rayon Company Slough. It must be noted here that officials of the duPont Rayon Company at Old Hickory informed Mr. Westfall on August 5 that little chemical waste was leaving this plant at that time, so the effect on the dissolved oxygen of the Cumberland River of any large run-off from the duPont Rayon Company mills was not determined.

It may be seen, however, from the graph that the ammonia content of the Cumberland River rose above the maximum limits for good fish fauna just below the mouth of the duPont Rayon Company Slough and continued above maximum to the east city limits of Nashville. Although 2 p.p.m. of ammonia is not lethal to most adult warm-water fish, this quantity of ammonia is detrimental to fish life (Ellis, 1936) and is indicative of definite organic pollution. Sewage from Old Hickory and organic wastes from the duPont Rayon Mills (streamers of fibrous wastes were found attached to stones, brush and other objects in the Cumberland River for some distance below the mouth of the duPont Rayon Company Slough), must be regarded as contributing to the stream ammonia between Old Hickory and Nashville.

The biochemical oxygen demand of the Cumberland River at Old Hickory above the duPont Rayon Company Mills, Station "A", was 2 p.p.m. for a 10-day test, and at Shelby Point, Station "B", 3 p.p.m. for a 10-day test. These values are not high, but indicate the presence of some organic matter in the stream.

From Old Hickory to Station "G", i.e., to the vicinity of the L. and N. R.R. Bridge at Nashville the dissolved oxygen content of the Cumberland River was satisfactory to good. However, from Station "G" to Station "I", just above Lock I the dissolved oxygen fell rapidly to a level not only detrimental but lethal for many fish. The dissolved oxygen for Cumberland River even after passing the dam at Lock I, which mechanically causes some reaeration of water, remained at levels presenting serious hazards to fish life, as far downstream as Station "L", some 16 miles below Nashville. At Stations "L" and "M" the dissolved oxygen of the flowing stream water had returned to levels favorable for fish life, although the deposits of sludge and wastes on the river bottom held the dissolved oxygen of the water near the bottom to below 3 p.p.m. even at Station "M" which is approximately 20 miles below Nashville.

Coordinate with this rapid decline of dissolved oxygen in the water of the Cumberland River during the passage through the City of Nashville is a striking rise in the biochemical oxygen demand. The biochemical oxygen demand of the river water at the city limits (east side) was 2 - 3 p.p.m. for a 10-day test, but at Station "G" near the L. and N. R.R.Bridge the B.O.D. had risen to 8 p.p.m., and at Station "I" to 14 p.p.m. for a 10-day test. The B.O.D. value, as well as the dissolved oxygen, and ammonia values, are for the flowing stream water, mixed of course with the various sewages and other effluents which are poured into the Cumberland River. In the vicinity of the sewers and in some of the more quiet portions of the stream, near Station "I" for example the B.O.D. rose to 20 p.p.m. or more for a 10-day period and the dissolved oxygen fell to almost zero.

The biochemical oxygen demand in spite of the rise in dissolved oxygen content of the river was still high, 10-12 p.p.m. for a 10-day test, 16 miles below Nashville. This condition was expected of course since the heavy load of organic waste given to the Cumberland River in passing through Nashville would not be consumed in 16 miles under conditions existing in August 1936.

These findings on biochemical oxygen demand show definite organic pollution of the Cumberland River waters as they pass through Nashville, since the biochemical oxygen demand exceeds the dissolved oxygen carried by these waters between Station "G" and Station "L" or beyond; and, also that the reaeration of the Cumberland River waters is insufficient to meet this demand in the city area and downstream for over 16 miles, since the dissolved oxygen remains at levels detrimental or lethal to fish life from Station "G" to Station "L".

The ammonia rose from 2 p.p.m. at the east city limits to nearly 4 p.p.m. at Station "F", just above Nashville city Sewer 7, and remained well above the maximum limits for good fish fauna (1.5 p.p.m.) for 20 miles downstream below Nashville. Judging from the B.O.D. at this point the ammonia would probably continue high beyond Station "M" the most downstream station at which samples were taken in the survey.

b. Bottom conditions.--Bottom conditions were found to be fair for fish life in the Cumberland River between Old Hickory and the east side city limits of Nashville, that is, although there were many places in this stretch of river where undesirable conditions were found there were on the other hand areas favorable to fish life.

However, from Station "E" downstream through Nashville to Station "L", a point some 16 miles below, bottom conditions were extremely bad. Layers of foul decomposing sludge from which quantities of gas rose whenever the bottom was disturbed, blanketed the bottom of Cumberland River in this sector, (Stations "E" to "L"), and the bottom fauna where present at all

was reduced almost entirely to leeches and sludge worms (Tubificidae) which forms in general are indicative of acute or septic pollution. Tubificid worms were so abundant near some sewers and waste outlets that the river bottom appeared red as one looked through the water at these huge colonies of reddish worms on the river bottom.

The bottom findings may be summarized by the statement that from Station "E" to Station "L" the bottom conditions as regards gases, sludges, and organic debris were such as to make the survival, much less the maintenance, of normal bottom fauna such as is found in average streams in the Mississippi System, impossible.

c. Discussion of water conditions.—Collectively the field work and analyses on the waters and the bottom of the Cumberland River in the Nashville area show acute organic pollution of this river from Station "G" that is, near the L. & N. R.R. bridge, downstream from some 20 miles below the City of Nashville, and that conditions varying from very detrimental to definitely lethal for fish and other aquatic life obtained for the most part throughout this sector of 30-35 miles of the Cumberland River.

It is true that fish were found in this area, that is, between Station "G" and Station "I", suckers, carp and occasional spinny-rayed fish were observed by our field party, but the presence of these fish in this area can not be construed as proving conditions to be satisfactory or even harmless to fish. It is well established that fish will often move into polluted waters where conditions are distinctly harmful to fish life, attracted by food or various chemical stimuli which are not so well understood, and that weakened by the unfavorable conditions of the polluted waters these fish readily succumb to certain fish diseases or to some abrupt change in river conditions, as a sudden introduction of a quantity of industrial waste which in normal waters might be relatively innocuous.

Three principal sources of the acute organic pollution in the Nashville area were determined:

1. The enormous quantities of untreated municipal sewage (chiefly domestic sewage) poured into this relatively slow moving portion of the Cumberland River by the 18 or more city sewers of Nashville and West Nashville.

2. The untreated wastes from the two packing plants and several small butchering houses.

3. The waste waters from five large laundries.

Collectively these three sources supply the bulk of the organic wastes received by the Cumberland River in the Nashville area. It is difficult to evaluate the individual contributions from these three sources since the presence of any one of these wastes augments the detrimental action of the other two, but from our analyses and field observations there seems no question but that the chief source of this organic pollution is the untreated municipal sewage and were this condition corrected the waste waters from the laundries would certainly be much less detrimental than they are at present, since under existing conditions the waste waters from the laundries with their organic loads and soap residues are emptied in water already heavily polluted with untreated municipal sewage. The wastes from the packing plants, noisome and spectacular as they are, must also be considered in the same light as the laundry wastes until the municipal sewage problem is corrected. Before finally discussing remedial measures and the relative importance of the several known sources of stream pollution in the Nashville area, the specific industrial wastes, other than those contributing organic material (packing plants and laundries) must also be considered.

INDUSTRIAL WASTES

During the course of the field work effluents from the principal industrial concerns pouring material into the Cumberland River in the Nashville area were obtained at the points of entry into the river and at the sources of these effluents in the factories themselves. In this connection we wish to gratefully acknowledge the cooperation of the various plant chemists and superintendents who assisted in the sampling work at the several concerns visited by us.

In evaluating the toxicity of industrial effluents, the dilution of the active substances by waste waters from the plant and the detoxification of these active substances by conditions or materials encountered by the effluent during its passage from the plant to the river must be considered.

Since the output of the active substances which are detrimental to fish life and the dilution of these substances by waste waters and other materials used in the plant often vary with the phases of the chemical procedures in the plant, the pollution hazards of any given effluent must be computed from the concentrations of the active substances which are lethal or damaging to fish life, regardless of the amount of these substances carried by the effluent at any given time. These lethal values must also be correlated with the maximum concentrations of these active substances which could occur in the effluent from any particular plant at any time. In respect to the industrial rights and trade processes of the various concerns which cooperated with us in this work no details of chemical processes are presented here. Our findings on the effluents are listed under each concern visited and the dilutions and lethal values refer to the active substances and to the effluent as poured into the river.

Victor Chemical Works.—The effluent from this plant is a strongly acid waste varying from pH 1.3 to pH 5.7, and in specific conductance from 336 to 2,044 mho x 10^{-6} at 25°C., in the samples studied. This effluent as it entered the river carried in some samples as high as 15,200 ppm. of solids. The bioassays showed the active substances in this effluent to be lethal to fish life in concentrations as low as 60 ppm. or in any combination in which the pH of the water receiving this effluent attained an acidity of pH 4.7 or greater, as the result of the addition of this effluent. The waste entering the Cumberland River from the Victor Chemical Works on August 6 at the time of the collection of these samples would have required at least a 1:10 dilution to have been brought below lethality for fish life.

Tennessee Fertilizer Company.—The effluent from this concern was a strongly acid waste with an average acidity in the samples studied of pH 1.6 and specific conductance of 27,067 mho x 10^{-6} at 25°C. This effluent was lethal for fish life in dilutions as low as 82 ppm. or in combinations which gave the water receiving this effluent an acidity of pH 5.0 or greater as the result of the addition of the effluent. This waste as entering the Cumberland River at the time these samples were taken would require a dilution of at least 1:60 to render it non-lethal for fish life.

Teas Extract Company.—The effluent from this plant was an acid waste averaging pH 5.0 in the samples studied, a specific conductance of 400 mho x 10^{-6} at 25°C., and carrying 3,650 ppm. of solids. The mixture of active principles (chiefly tannic acid and its derivatives) from this effluent was lethal to fish in dilutions as low as 120 ppm. This value would require a dilution of the effluent as it entered Richland Creek at the time these samples were taken of at least 1:30.

Nashville Heat and Gas Company.—This concern was pouring a typical coal gas factory effluent into the river. This waste was strongly alkaline with a pH 8.6 to pH 9.0 and specific conductance of 2,118 mho x 10^{-6} at 25°C. at the time of sampling. The high toxicity of coal gas factory effluents is well known (Shelford, 1917; Ellis, 1937) and need not be discussed here. The Nashville Heat and Gas Company effluent at the time of sampling was lethal for fish in quantities as low as 37 ppm. of active substances, which would require a dilution of at least 1:20 to render this effluent non-lethal for fish life, disregarding the known cumulative effects of several of the coal gas wastes poisons, such as phenol, on fish life.

Heinz Pickle Factory.—The effluent as collected from this plant carried little solid matter either in solution or suspension (700 ppm. being the maximum amount found) and varied in hydrogen-ion concentration from pH 5.5 to pH 7.5. Bioassay tests showed this effluent as collected to be harmless to fish in concentrations as high as 1:10.

Federal Chemical Works.—The effluent from this plant was strongly acid ranging from pH 1.2 to pH 3.2 in the sample studied, and in specific conductance from 2,230 to 36,808 mho x 10^{-6} at 25°C., i.e., the effluent as it entered the river contained a large amount of ionizable material. The total solids of this waste varied from 620 to 11,060 ppm. The mixture of active principles as found in this effluent was lethal for fish life in dilutions as low as 182 ppm. and would require a dilution of the effluent as entering the river at the time these samples were collected, of at least 1:70 to render this waste non-lethal to fish life.

duPont Rayon Company.—As has been shown in other studies by the writers (at Rome, Georgia, and elsewhere) several of the waste products discharged from rayon mills are highly toxic to fish. At the time of the present investigations in the Nashville area one of us, Dr. Westfall, was informed by the duPont officials that very little chemical waste was leaving the plant at Old Hickory. The effluent collected from the duPont Company's main outlet at that time was not lethal to fish in concentrations as high as 1:10.

Mead Paperboard Company.—The combined effluents from this plant varied greatly in composition and in total solids ranging from pH 6.4 to pH 9.0 and the specific conductance from 957 to 7,805 mho x 10^{-6} at 25°C. The total solids were as low as 115 ppm. in certain samples and as high as 20,060 in others. At the time of sampling Richland Creek which receives the wastes from both the Teas Extract Company and from the Mead Paperboard Company, was heavily polluted and the waters were dark blue to black in color. As effluents from sulphite process paperboard works have been studied in detail and are known to carry several toxic substances as mercaptan and various sulphur derivatives, and also to create an oxygen demand (Ellis, 1937), dilution values for the effluents from the Mead Paperboard Works are not given. These effluents are known to present serious pollution hazards, and our field work in the vicinity of Richland Creek on the Cumberland River revealed ample evidence both in water and bottom conditions of heavy pollution from the combined Richland Creek effluents from the Teas Extract and Mead Paperboard Companies' plants.

Miscellaneous.—Several other concerns, namely, the Buford Brothers, the G. L. Herbert Sand Company, the Hickory Spoke Manufacturing Company, the boat unloading station of the Gulf Refining Company, the Reads Fertilizer Company, and the Walnut Veneer Products Company, which on occasion pour wastes into the Cumberland River and tributaries in the vicinity of Nashville, were also visited.

At the time of our survey these concerns were either not pouring wastes into the river or were discharging relatively innocuous wastes which did not require special consideration. However, we were informed that several of these plants at times discharge quantities of toxic wastes into the Cumberland River, either directly or indirectly.

Although we can only make definite statements based on the effluents examined by us we must add, however, from the descriptions of the processes used by these several concerns that the wood working plants would present dangerous pollution hazards if these plants dump their wood steeping waters into the river, that, the fertilizer works would have chemical wastes of high potential toxicity, and that, the loss of crude or refined oil and oil products into the river during the unloading of these commodities is known to be a definite pollution hazard elsewhere.

GENERAL SUMMARY

The bioassays and analyses of the effluents from various manufacturing concerns in the Nashville area show that the effluents from the Victor Chemical Company, Tennessee Fertilizer Company, the Teas Extract Company, Nashville Heat and Gas Company, the Federal Chemical Works, and the Mead Paperboard Company were carrying substances highly toxic to fish life at the time these investigations were made, and that the wastes as collected from the Heinz Pickle Factory and the duPont Rayon Mills were relatively non-toxic to fish.

From the data, both field and laboratory, as obtained by us in the Cumberland River investigations in the Nashville area, the following statements can be made:

1. The Cumberland River arrives at the east city limits in a fair condition at least, as regards fish and fisheries.

2. The Cumberland River in its passage through the City of Nashville receives an enormous load of organic pollution, from the untreated sewage contributed by the 18 or more city sewers, from the untreated wastes of two packing plants and several small butchering concerns and from the waste waters of five laundries.

3. The river bottom of the Cumberland River has been fouled for some 20 or 30 miles below the City of Nashville to an extent that the normal bottom fauna (which contributes material to fish food as found in unpolluted inland streams) has been replaced almost entirely by those forms tolerant of extreme pollution.

4. The waters of the Cumberland River in this sector, that is, from the east city limits of Nashville to a point approximately 20 miles below the west city limits are so depleted of dissolved oxygen, so loaded with organic material (as shown by biochemical oxygen demand) and with ammonia and other gases liberated by the decomposition of this load, that conditions varying from acutely harmful to lethal for fish life exist in this sector of the Cumberland River.

5. The various factory effluents as liberated under the usual conditions (excepting packing plants and laundries), although carrying toxic substances into the polluted waters of the Cumberland River, play only a

small part in the day by day condition of the Cumberland River in the Nashville area, as compared with the detrimental action of the untreated sewage and untreated wastes from packing plants.

6. The practice of dumping large volumes of factory effluents suddenly and at irregular intervals into the already heavily polluted Cumberland River which practice was reported to us by various persons and which was verified by our own field studies of shore and bottom conditions, is the immediate cause of the sudden death of large numbers of fish in the Cumberland River in the Nashville area, that is, the water and bottom conditions in the Cumberland River are so bad due to the organic pollution described above, that the sudden inrush of a large quantity of industrial waste of even low toxicity suffices to quickly render the barely sublethal conditions existing in the Cumberland River into conditions lethal for fish life, with the resultant death of large numbers of fish. The synergistic actions of industrial pollutants and organic pollution are well known.

RECOMMENDATIONS

If fish and fisheries are to be restored or even protected in the Nashville area the following conditions must be met:

1. The dumping of untreated municipal sewage and untreated packing plants effluents into the river must be stopped.

2. The laundry waste waters now poured into the river in this area should be diluted with 3 or 4 volumes of fresh water before these wastes are flumed into the river, that is, the laundry wastes as now poured into the Cumberland River in the Nashville area should be greatly diluted.

3. The dumping of large volumes of industrial wastes suddenly into the river even during periods of high water by industrial concerns should be prohibited, as the large volumes of effluents such as are poured in when vats are emptied or tanks recharged, can easily kill large numbers of fish before a non-lethal dilution is accomplished by stream action.

4. All effluents both regular and occasional should be diluted, neutralized or detoxified, well below the non-lethal level before they are poured into the stream. Actual tests have shown dilution to be of great importance in the disposal of industrial effluents, and methods of treatment are available for several types of chemical wastes.

5. Cumulative effluents and effluents which are not readily diluted or destroyed by stream action, such as gas house wastes, oils, and wastes carrying heavy metals or large quantities of sludge producing substances, should be entirely excluded from the stream.

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Explanatory Note

This mimeographed Special Scientific Report has been published in limited quantity for the official use of Federal offices and cooperating agencies. It presents the results of an investigation of specific problems and is intended as a guide for administrative and legislative action. The data may be incorporated in a complete publication to be printed and released at a future date.